ADAPTIVE SERVICE FUNCTION ASSIGNMENT WITH SOFTWARE DEFINED RADIO FOR COMPOSITE WIRELESS SYSTEMS

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ABSTRACT

Services and applications provided over wireless systems are increasing every year. However, because the quality of service (QoS) differs from service to service, it is difficult to provide all services and applications using one wireless system alone. To solve this problem, we propose an adaptive service function assignment that efficiently uses wireless systems. We evaluated its performance in computer simulations and show the efficiency of the proposed scheme based on the simulation results. We also considered the network architecture of composite wireless systems that use the adaptive service function assignment method.

1. INTRODUCTION

Services and applications provided over wireless systems are increasing every year. Additionally, they encompass a spectrum ranging from conventional services, such as telephone and e-mail, to advanced services, such as videophone, video streaming, and electronic commerce. However, because the QoS differs from service to service, the wireless system must satisfy the various service and application requirements.

On the other hand, wireless systems have sprung up like mushrooms. 2G mobile communication systems, such as PDC and GSM, feature a large coverage area and low transmission rate. Wireless LAN systems feature a small coverage area, high transmission rate, and security vulnerability. Thus, features such as the transmission rate, coverage areas, authentication methods, and encryption schemes are different in each wireless system.

For these reasons, it is difficult to provide all services and applications using one wireless system alone. It is now possible to flexibly adapt to and comply with various user requests by combining multiple wireless systems in heterogeneous wireless system environments [1]-[5]. Moreover, Mitola studied cognitive radio technology, in which the frequency or wireless system was selected based on the actual application environment [6].

Many vertical handover techniques have been studied [7]-[9]. These techniques switch the wireless systems based on QoS and the user's policy under composite wireless systems. Switching to wireless systems enables seamless communication and improves throughput. However, the vertical handover techniques do not always satisfy the QoS, because they simply switch wireless systems.

In addition, we now have technology that uses two or more wireless systems and includes multilink protocols [10][11]. Even wireless systems with low transmission rates, can offer a high-speed data communication services by bundling the data links. This enables us to realize flexible and effective data communications by combining multiple wireless systems. However, if the data links of a wireless system with a low QoS level are multiplexed, the QoS level of the total wireless system will be degraded even more.

To solve this problem, we focused on the QoS of each wireless system and propose a novel integrated service concept for composite wireless systems that efficiently assigns the service functions to different wireless systems, based on each system's QoS.

Section 2 of this paper describes the composite wireless system concept using the adaptive service function assignment method. Next, we describe the adaptive service function assignment method in detail and evaluate its performance by computer simulations in section 3. Section 4 describes the network architecture for our proposed method. Finally, section 5 gives a brief conclusion.

2. COMPOSITE WIRELESS SYSTEMS WITH ADAPTIVE SERVICE FUNCTION ASSIGNMENT

We propose a composite wireless system that applies the adaptive service function assignment method to separate the user and control data and transmits it using an appropriate wireless system, while considering the QoS of the various systems to be integrated. Figure 1 shows the concept of the integrated service in composite wireless systems using the adaptive service function assignment. In Fig.1, since wireless system A satisfies the quality requirement of the data rate requested by the application, the software defined radio (SDR) terminal transmits user data using wireless system A.. However, the quality of the security standards and the mobility of wireless system A do not satisfy the QoS requested by the application. Therefore, an SDR terminal transmits a security key used in the integrated services via wireless system B, because it satisfies the security quality requirements. Additionally, the mobility control data used in the integrated service is transmitted via wireless system C, because the wireless system satisfies the mobility control requirement. Thus, the application is provided as integrated service.

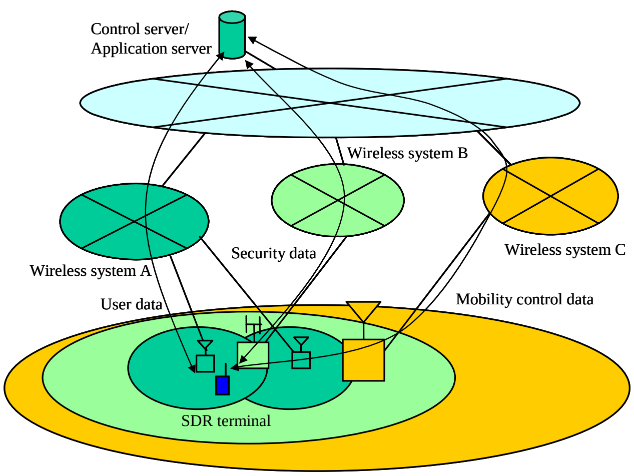

Fig.1 Composite wireless system with adaptive service function assignment

3. ADAPTIVE SERVICE FUNCTION ASSIGNMENT

3.1. Proposed adaptive service function assignment method

The adaptive service function assignment method selects the appropriate wireless system, based on the QoS requirements. Therefore, the QoS application and wireless system requirements are parameterized using QoS evaluation criteria to choose a system that meets the QoS requested by an application in advance. Figure 2 shows the relationship between the application and wireless system's QoS requirements. The QoS requirements of an application are related to many QoS evaluation criteria of the wireless system. It should be noted that this evaluation criteria does not depend on other features, when matching the wireless system's characteristics to the parameters. The transmission rate, security, mobility, etc. are included as QoS evaluation criteria. Table 1 shows an example of the parameterized requirement table. In the same way, the characteristics of each wireless system are tabulated using the QoS management table shown in Table 2. Next, we parameterize the hardware resources, such as memory, processor power, and so on, consumed by the system software running on the SDR terminal. Table 3 shows an example of a hardware resource table compiled from these results. The adaptive service function assignment method chooses a combination of wireless systems that meet the QoS required by the service using Tables 1 and 2, and confirms the hardware resources using Table 3. After confirmation, the adaptive service function assignment method selects the combination of wireless systems.

Figure 3 shows the hardware configuration of an SDR terminal with the adaptive service function assignment method. The SDR terminal is composed of a service interface, a data manager, a wireless system selector, an SDR communicator, and three tables; the requirement, QoS management, and the hardware resource tables. The data manager manages the state of each wireless system, distributes data to the wireless system as control and user data, and integrates the control and user data received from each wireless system. The wireless system selector chooses the wireless system that best meets the requirements requested by the service using the parameters on the requirement table and the QoS management table and confirms the hardware resources using the hardware resource table. After confirmation, the wireless systems to be used are selected. The SDR communicator executes the wireless communication protocol.

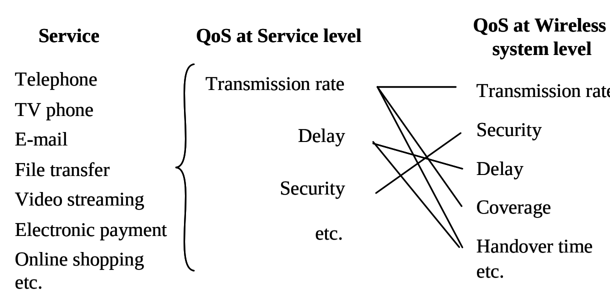

Fig.2 QoS relationship

Table 1 Requirement table

Service \ QoS evaluation criteria	A	B	....	N
Service 1	A1	B1		N1
Service 2	A2	B2		N2
⋮				
Service m	Am	Bm		Nm

Table 2 QoS management table

Wireless system \ QoS evaluation criteria	A	B	········	N
System a	Aa	Ba		Na
System b	Ab	Bb		Nb
⋮				
System n	An	Bn		Nn

Table 3 Hardware resource table

Wireless system \ Hardware resource criteria	α	β	········	ω
System a	α a	β a		ω a
System b	α b	β b		ω b
⋮				
System n	α n	β n		ω n

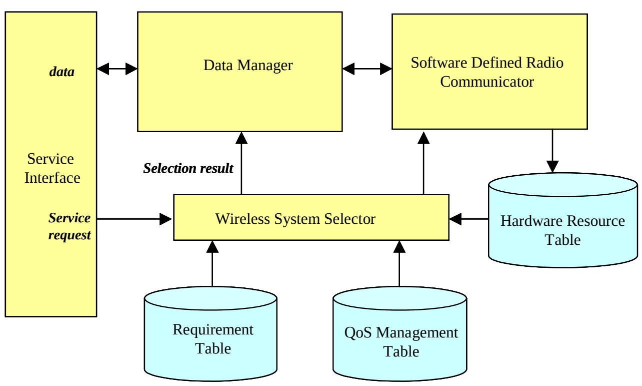

Fig.3 Hardware configuration of the SDR terminal

3.2 Perfomance evaluation

We evaluated the performance of our method using computer simulations. The simulation model and conditions are shown in Figure 4 and Table 4, respectively. The composite wireless system in Figure 4 is composed of three different wireless systems. The user can access one service that includes a telephone, video streaming, electronic payment, and online shopping. We assumed the ratio of the telephone and video streaming and electronic payment and online shopping to be 0.5 and 0.25 and 0.125 and 0.125, respectively. In the coverage area ratio, only wireless system A is 0.4, wireless systems A and B are 0.3, wireless systems A and C are 0.1, and wireless systems A, B, and C are 0.2. Tables 5 and 6 show the requirements of each service and the QoS characteristics of each wireless system. Under these conditions, we evaluated the success rate of the proposed method's service. At this time, we assumed that the SDR terminal has a sufficient hardware resource, and the SDR terminal remains fixed.

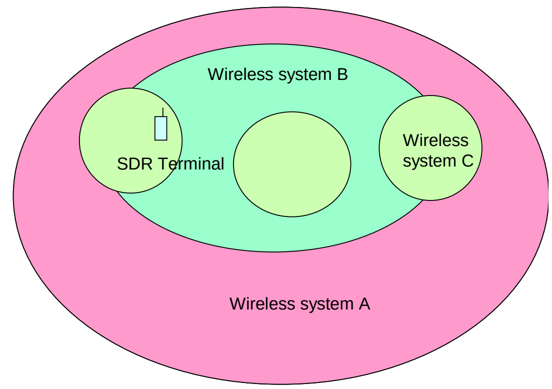

Fig. 4 Simulation model

Table 4 Simulation conditions

Service ratio	Telephone:0.5,Video streaming:0.25, Electronic payment:0.125,Online Shopping:0.125
Area ratio	A:0.4, A&B:0.3, A&C:0.1, A&B&C:0.2
Channel number	4ch/System A, 4ch/System B, 6ch/System C
Hold time	Exponential distribution, mean=120[s] (Telephone, Electronic payment) Exponential distribution, mean=600[s] (Video streaming, Online shopping)
Wait time	Exponential distribution, mean=600[s]

Table 5 Examples of service requirements

Service \ QoS evaluation criteria	Transmission rate	Security
Telephone	1	1
Video streaming	3	1
Electronic payment	2	3
Online shopping	3	3

Table 6 Examples of QoS management

Wireless system \ QoS evaluation criteria	Transmission rate	Security
Wireless System A	1	3
Wireless System B	2	3
Wireless System C	3	1

Figure 5 shows the evaluation results. The vertical axis is the success rate, and the horizontal axis is the number of users. The conventional method was enabled only for one wireless system that was used in the area near the SDR terminal. Therefore, the demand for online shopping failed, regardless of the SDR terminal's location, when conventional methods were applied. Based on the simulation results, we clarified the improvement in the service success rate using the proposed method, because we could use the multiple wireless system resources under low load conditions, compared with the conventional method. However, the success rate decreased compared with the conventional method that used only one wireless system under high load conditions because the proposed method uses multiple wireless systems, based on the QoS requirements of the service. In a word, the proposed method is especially effective when there is margin in the wireless system resources.

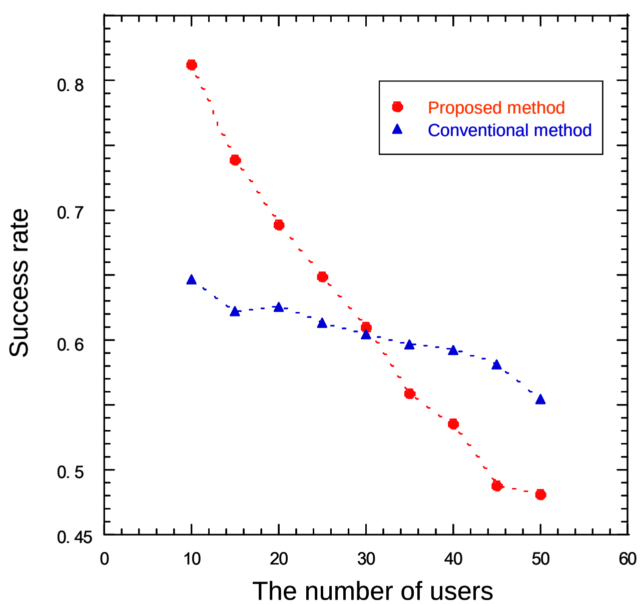

Fig. 5 Success rate vs. the number of users

4. NETWORK ARCHITECTURE

To execute our method, it must be installed on both the terminal and network sides. We will now look at setting up a control server that can apply the adaptive service function assignment method on the Internet, and set up control servers on the local networks of each wireless system.

4.1. Control server Internet arrangement

Figure 6 shows the network configuration for a control server set up on the Internet. Figure 7 is the sequence in which high-speed, high security data transmissions are implemented . Wireless systems A and B in Figure 6 are defined as wireless LAN and cellular systems, respectively. When the application starts, the wireless system selector on the SDR terminal chooses a wireless system based on the application requirements, and reconfigures the SDR terminal. Because the SDR terminal applies the adaptive service function assignment method, the SDR terminal transmits control information concerning security, such as authentication and encryption keys via cellular systems, and transmits user data via wireless LAN systems. First, the SDR terminal transmits the authentication request to the cellular system. After the SDR terminal has been authenticated. it transmits the application's authentication request to the application server through the control server, and then over the Internet through a cellular system. At this time, because wireless LAN system security is weak, the control server transmits the encryption key information used for authentication and data encryption of the wireless LAN system to the authentication server of the wireless LAN system and the SDR terminal. The control server transmits encryption key information to the SDR terminal through a cellular network. The SDR terminal is authenticated using a wireless LAN system by applying the received key information. User data is distributed to wireless LAN systems from the data manager of the SDR terminal, and then transmitted to an application server. At this time, wireless LAN system communication is encrypted with key information received over the cellular network. As a result, high security high-speed data transmission services can be offered.

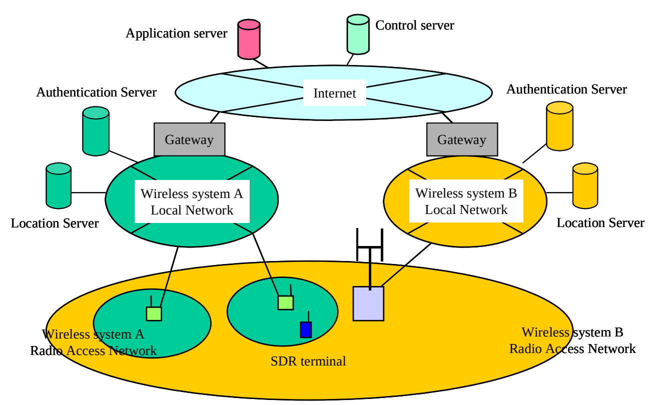

Fig.6 Control server arrangement over Internet

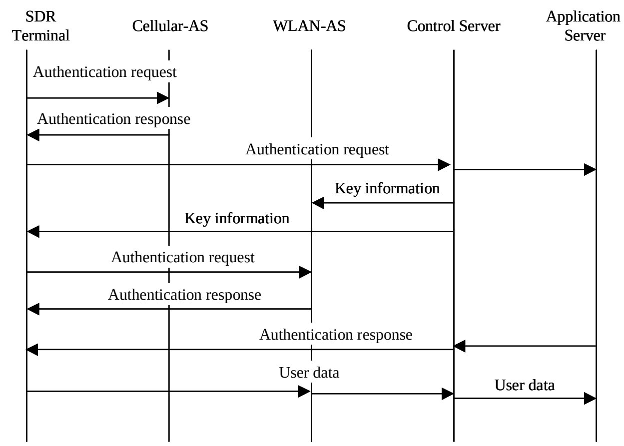

Fig.7 Sequence of control server arrangement over Internet

4.2. Local network control server arrangement

Figure 8 shows the network architecture by which the control server is arranged in each wireless system. Each wireless system is interconnected, as seen in Figure 8. The control server is arranged in each wireless system, and the control servers communicate with each other. Figure 9 shows the communication sequence by which the application shown in Figure 7 is executed in this network architecture.

When the application starts, the wireless system selector of the SDR terminal chooses a wireless system, based on the application requirements, and reconfigures the SDR terminal. The SDR terminal transmits security control information, such as authentication and encryption keys via a cellular system, and transmits user data using a wireless LAN system, as shown in Fig. 8. First, the SDR terminal transmits the authentication request to the authentication server of the cellular system. After the SDR terminal is authenticated, the SDR terminal transmits the application's authentication request to the application server through the control server over a local cellular system network. At this time, the cellular network's control server transmits encryption key information, used for authentication and data encryption of the wireless LAN system, to the wireless LAN's control server and SDR terminal. The wireless control server transmits the received encryption key information to the wireless LAN's authentication server. The SDR terminal is authenticated with wireless LAN system using the received key information. The application server transmits the authentication results to the control server of the cellular system. Afterwards, the cellular system's control server transmits the authentication results to the SDR terminal. The SDR terminal transmits the user data to the application server through a wireless LAN system. As a result, high security, high-speed data transmission services can be offered.

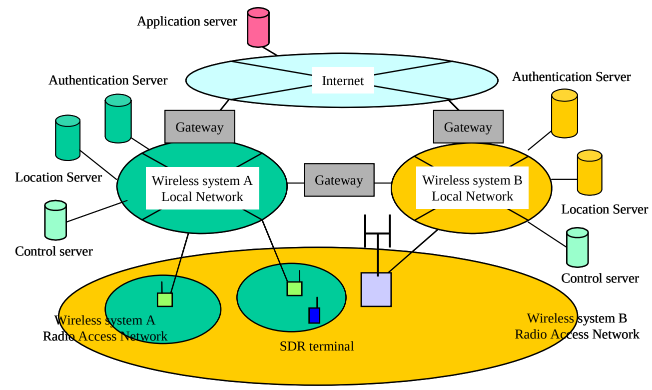

Fig.8 Control server arrangement over local network

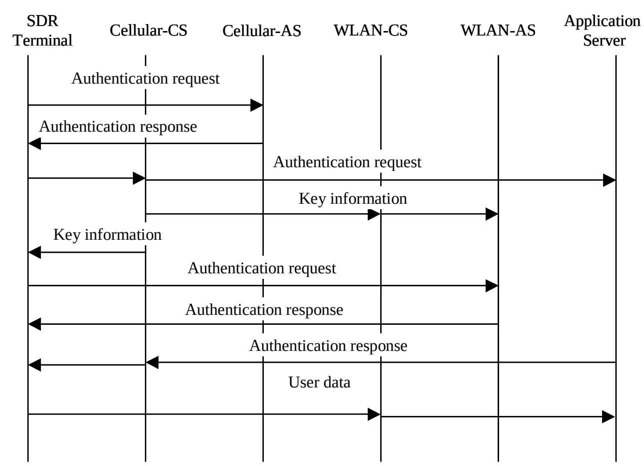

Fig.9 Control server arrangement sequence over local networks

4.3. Considerations

The control server arrangement over the Internet has advantages, such as a small number of control servers and a high affinity with existing networks, compared with the control server arrangement over each system's local networks. On the other hand, because controlling the communication sequence level of the wireless system is easier, the control server arrangement on the local network enables the combination of more flexible radio systems. On the other hand, the control server arrangement on the local network enables a more flexible combination of radio systems, because it can be easily controlled at the communication sequence level of wireless communication protocol. However, because it can be easily realized and managed, network architecture in which the control server is arranged over Internet is preferable.

5. CONCLUSIONS

We proposed an adaptive service function assignment method that separates the user and control data and transmits them using an appropriate wireless system, considering the QoS of the various systems to be integrated under the composite wireless system. The service success rate was evaluated by computer simulations and used to evaluate the proposed method. As a result, it improved the service success rate compared to conventional methods, because it can efficiently combine and use wireless systems under low load conditions. Moreover, we examined two arrangements for the control server that executed our method over the Internet and over the local networks of each wireless system. As a result, we obtained an excellent Internet arrangement with respect to a high affinity with legacy networks and the number of the control servers, compared with local network arrangements.

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